The Role of Robotic Outposts in Establishing a Permanent Presence in Space

Third Annual Carl Sagan Memorial Lecture

American Astronautical Society

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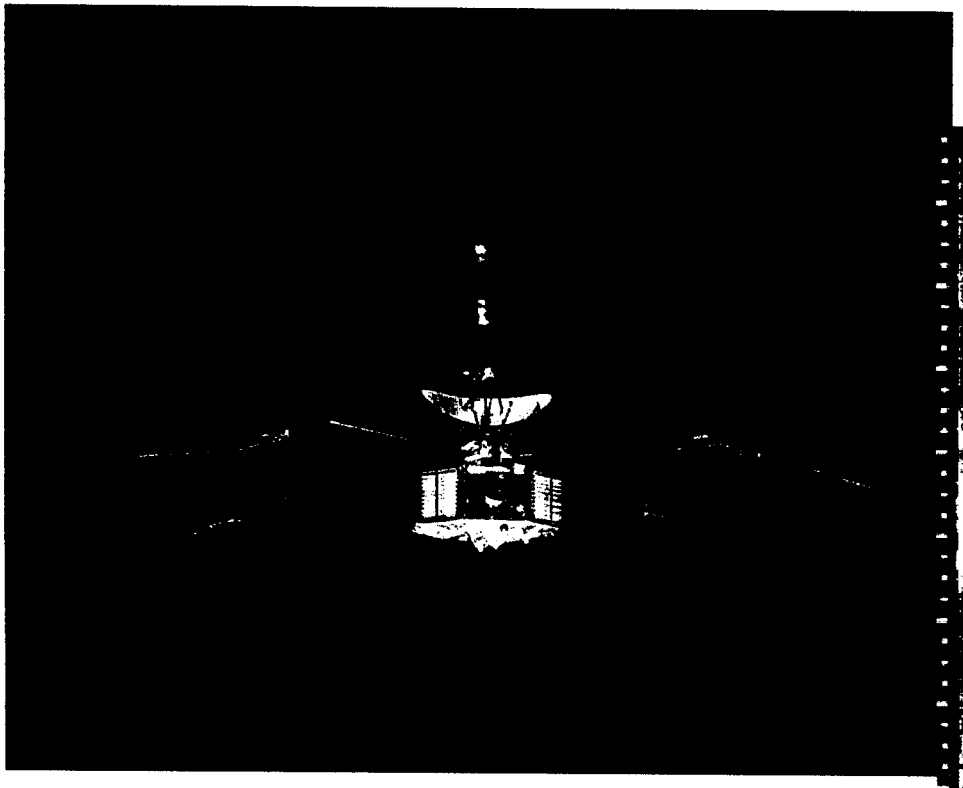
Jet Propulsion Laboratory
California Institute of Technology

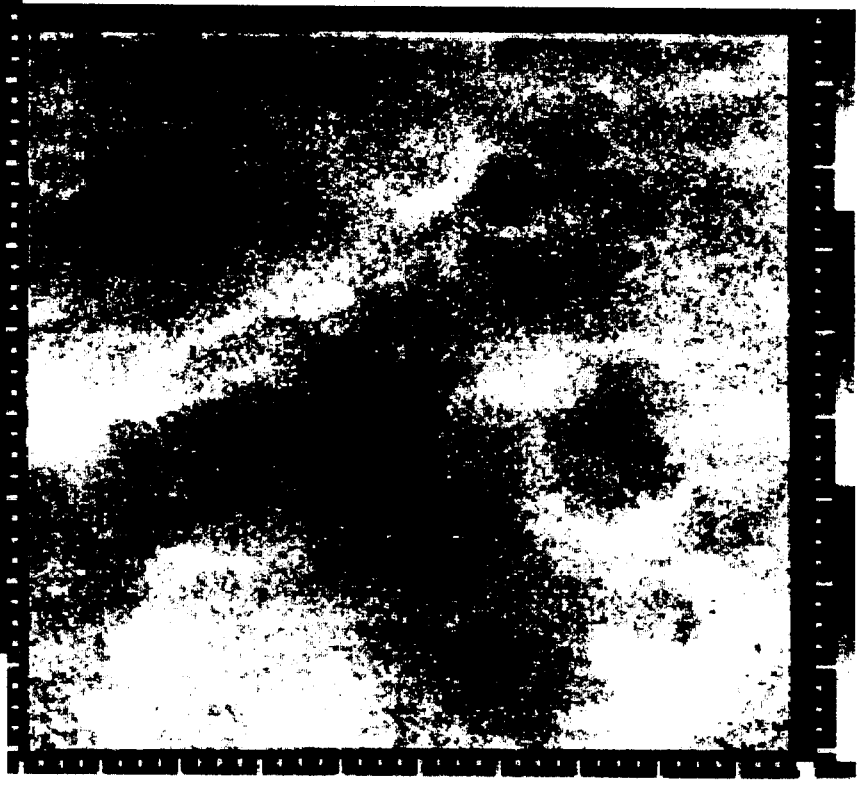
Topics

- The Eras of Space Exploration
- The Role of Robotic Outposts
- Establishing and Evolving a Permanent Presence
- Technologies
- Paving the Way for Future Exploration

The First Era: Getting There

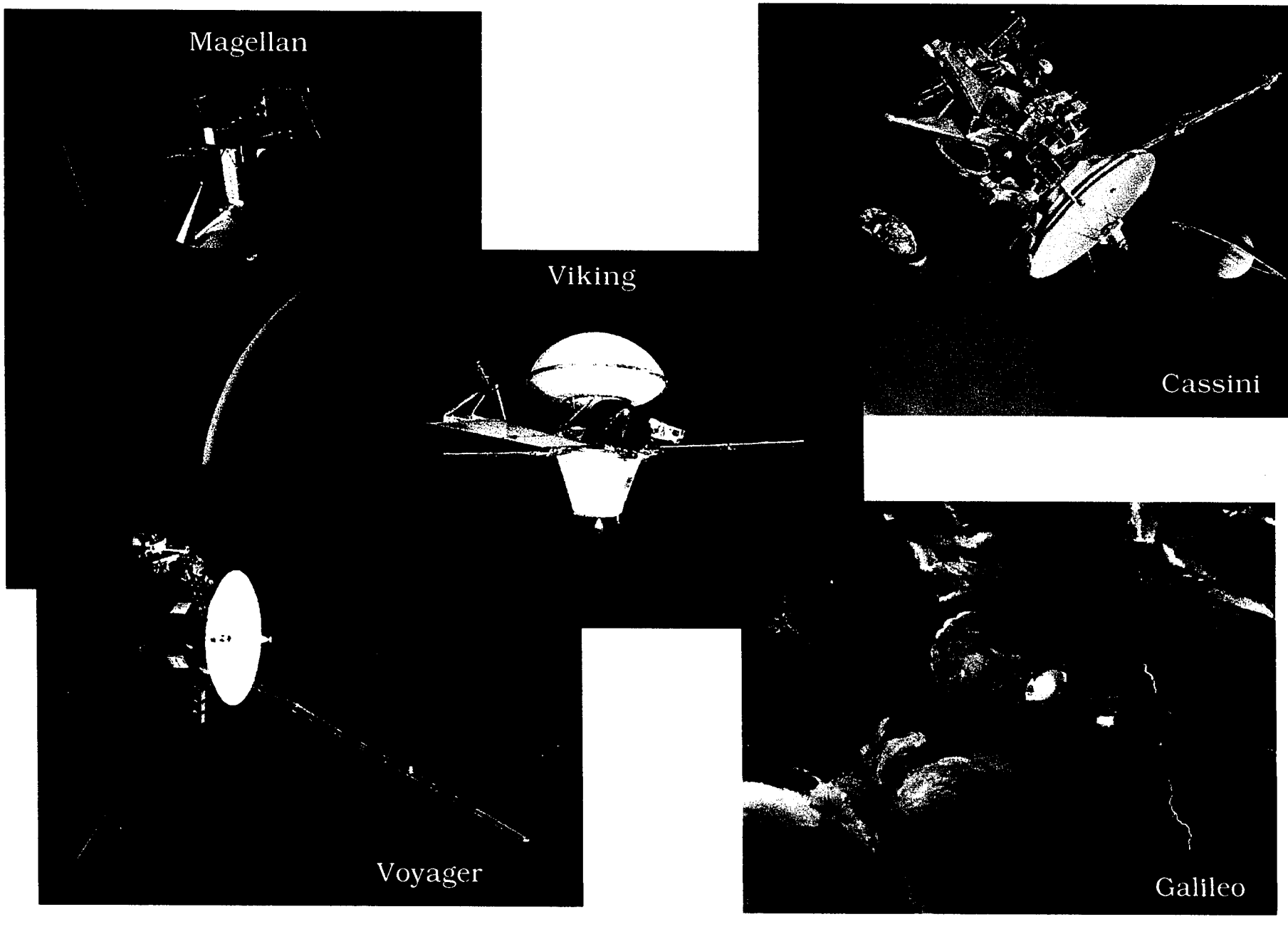


Mariner 4

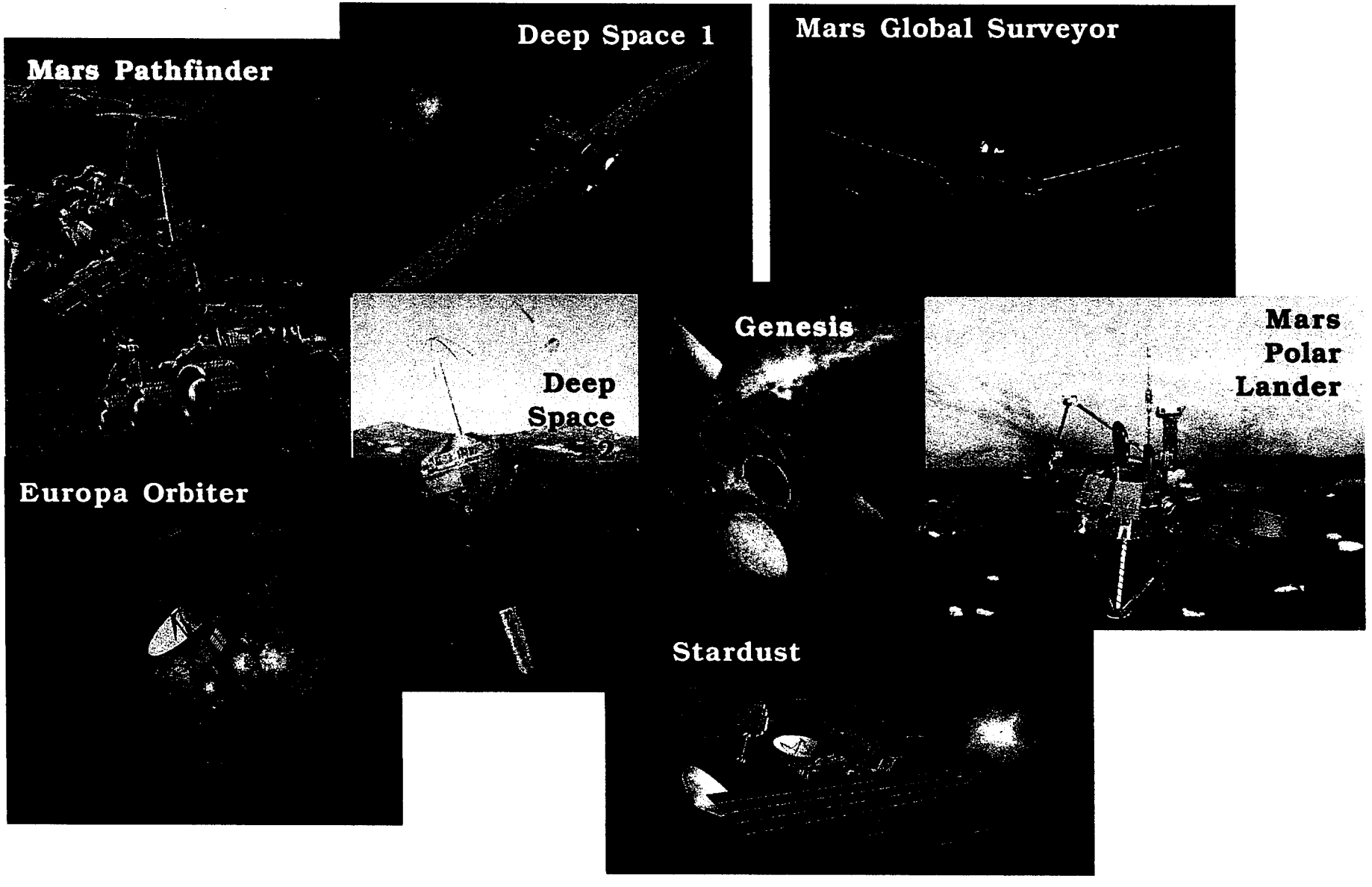


Mariner 4 View of Crater Rims -
Southern Highlands of Mars

The Second Era: Finding Out What's There



The Third Era: Going Often, Landing, and Bringing Samples Back



Second and Third Era Characteristics

Second Era	Third Era
Individual Projects	Programs of Linked Projects
Large, Comprehensive Observatories	Small, Focused Systems
Global Scale Exploration	Local Scale Exploration
Remote Sensing	*In Situ* Sensing

The Fourth Era: Permanent Presence

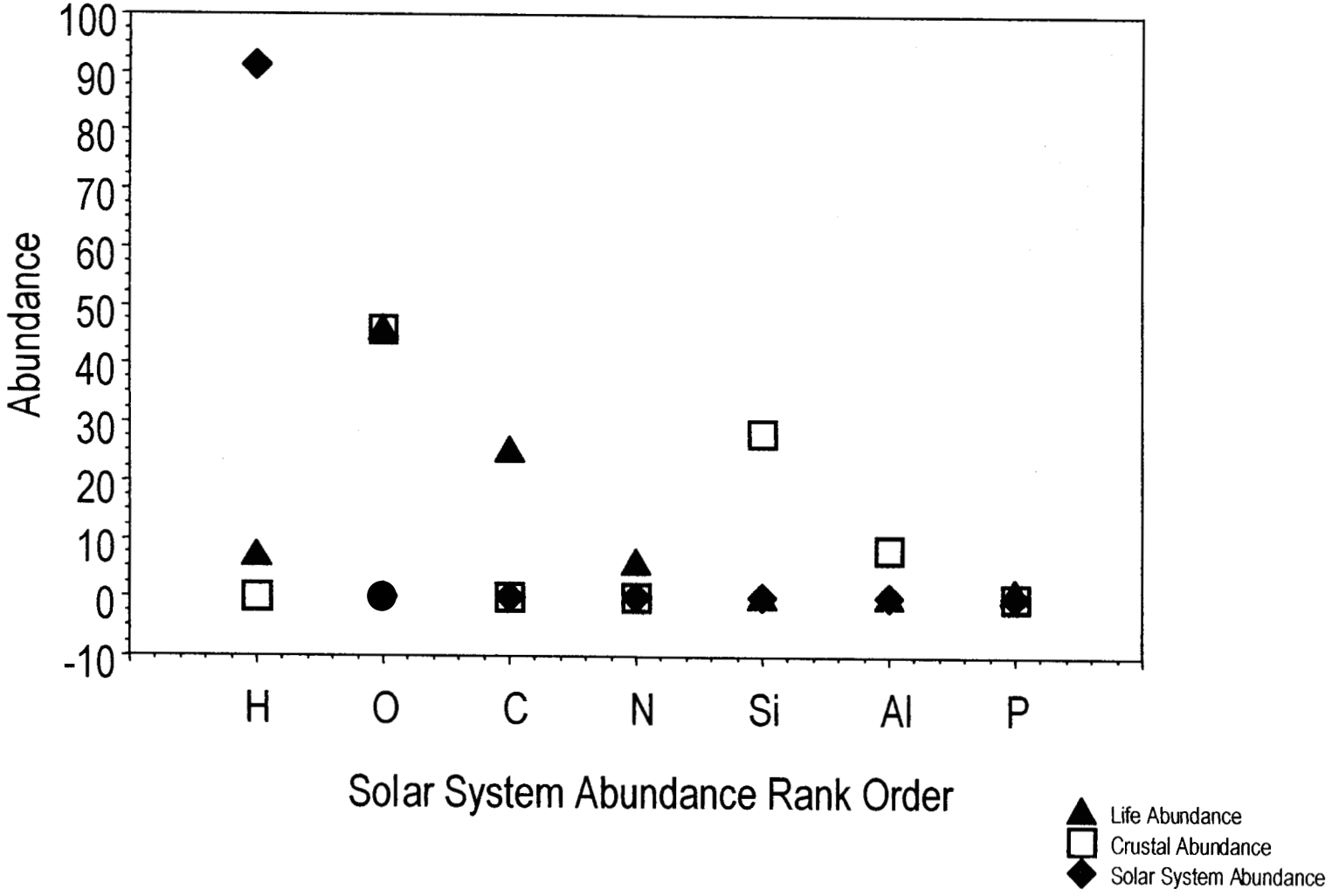
Third and Fourth Era Characteristics

Third Era	Fourth Era
Episodic Surface Activities	Continuous, Cooperative Operation
Localized Mobility	Long Range Mobility
Limited Power	Sustained, Substantial Power
Limited Communications	Continuous, High-bandwidth Network Communication
Bring Resources from Earth	Use *In Situ* Resources

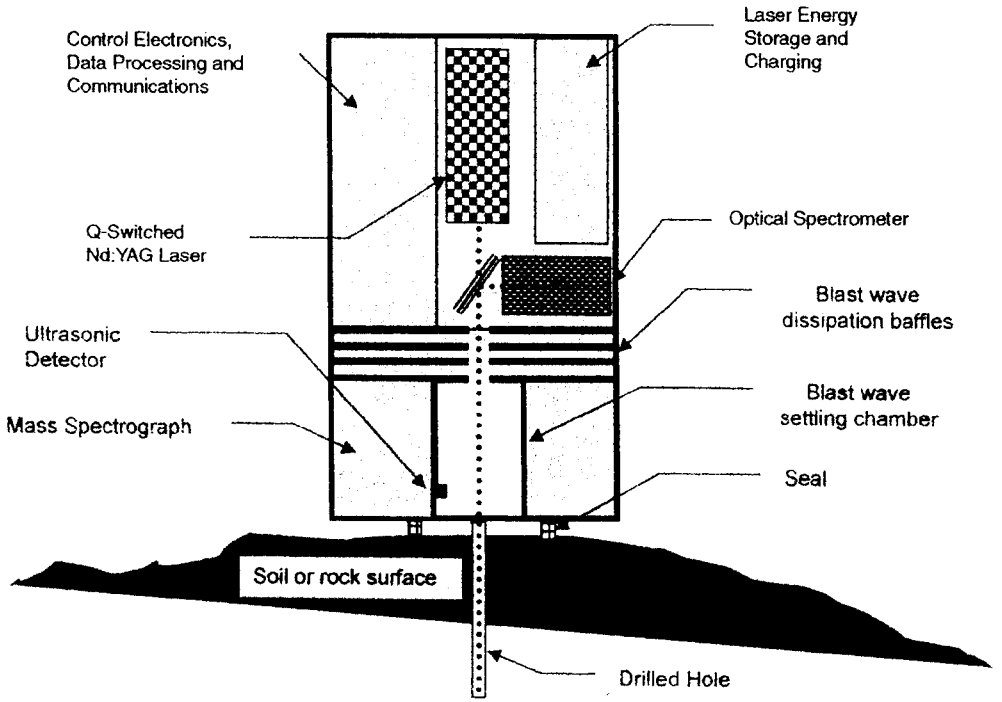
The Role of Robotic Outposts

- Advanced Scientific Activities
    - Search for Extant Life
    - Planetary History and Evolution
- Public Engagement
- Support Human Exploration
    - Understanding the Environment and Resources
    - Providing Infrastructure and Technology

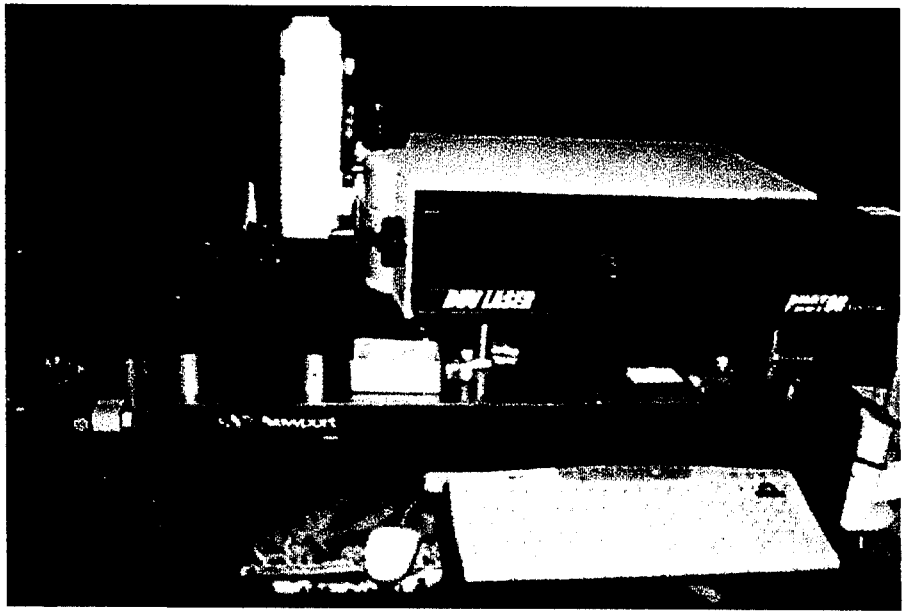
Elemental Abundance in Living Organisms and Earth's Crust

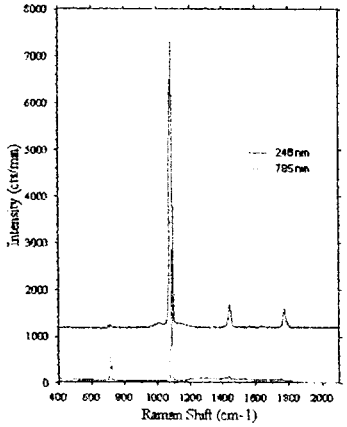


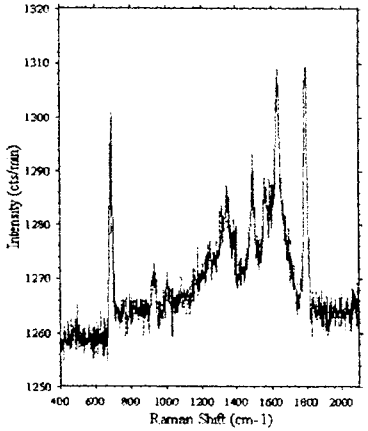
Enhanced Science:
Laser Ablation and Spectroscopic Analysis

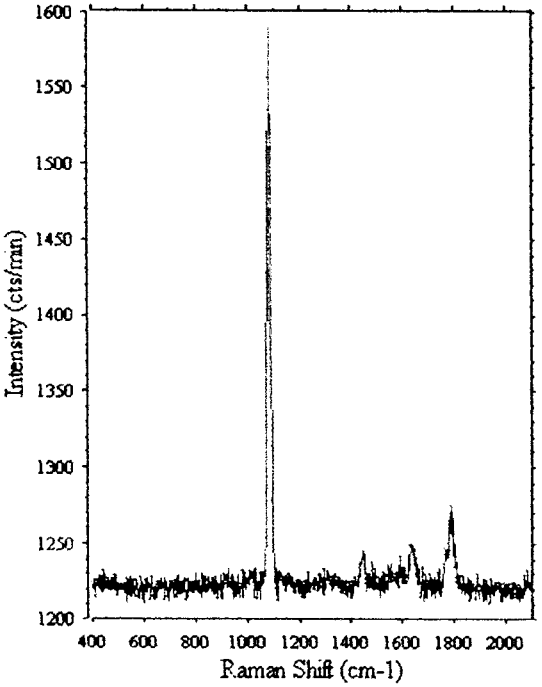


Enhanced Science:
Ultraviolet Raman Spectroscopy

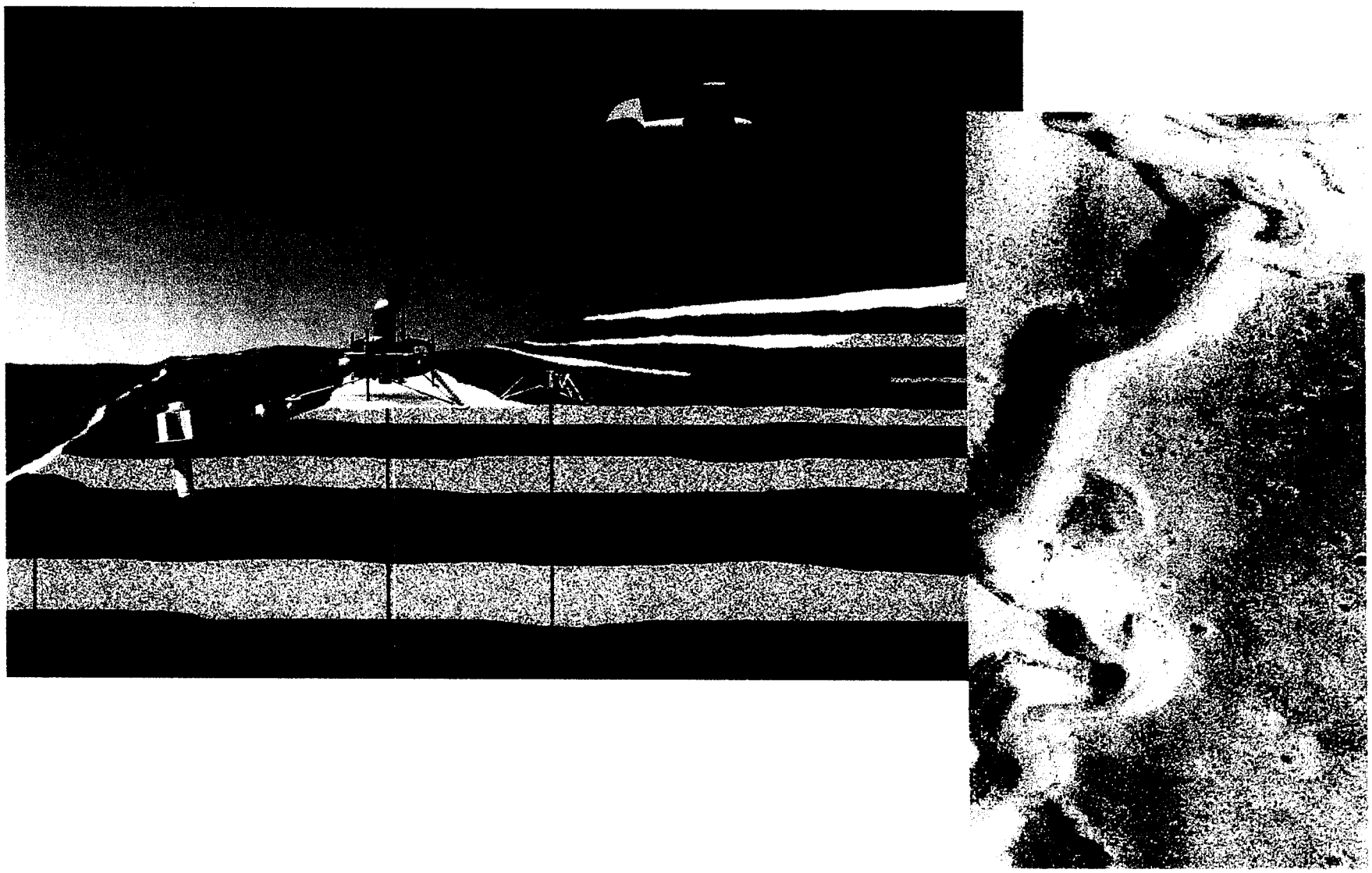




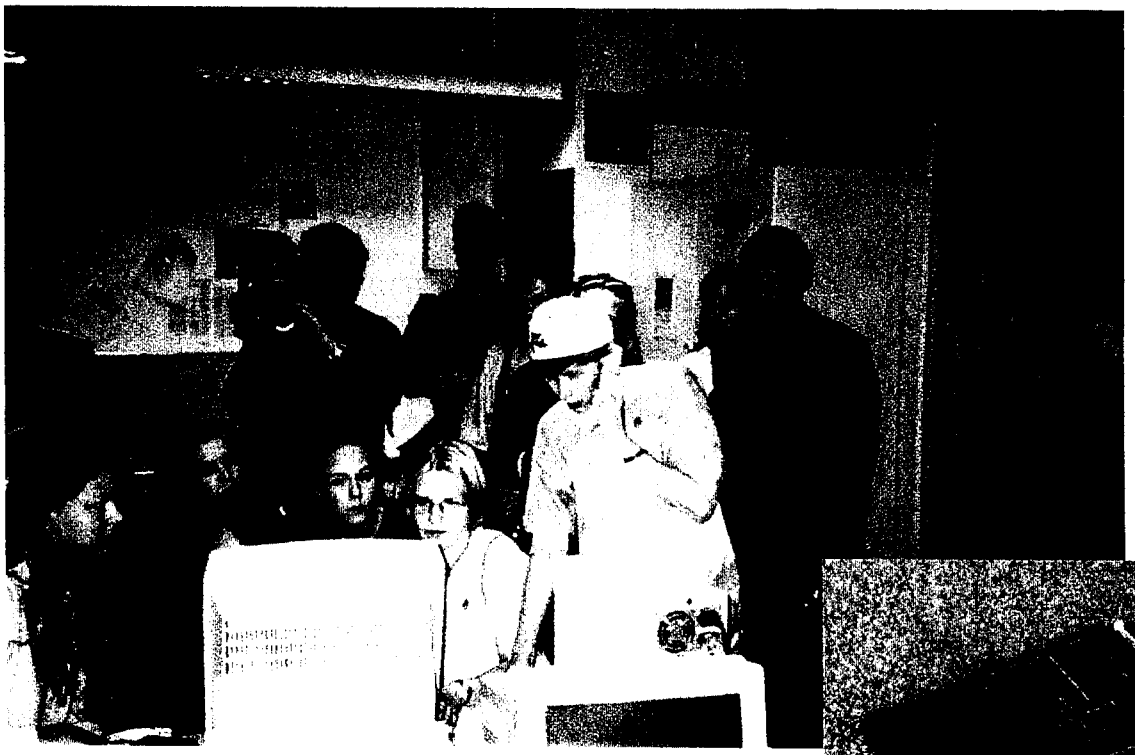


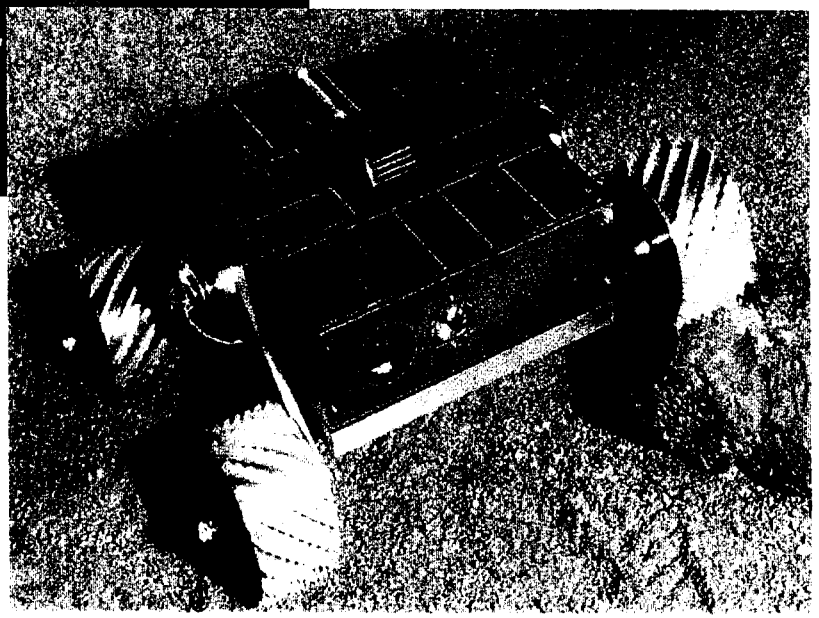


Planetary History and Evolution



Public Engagement



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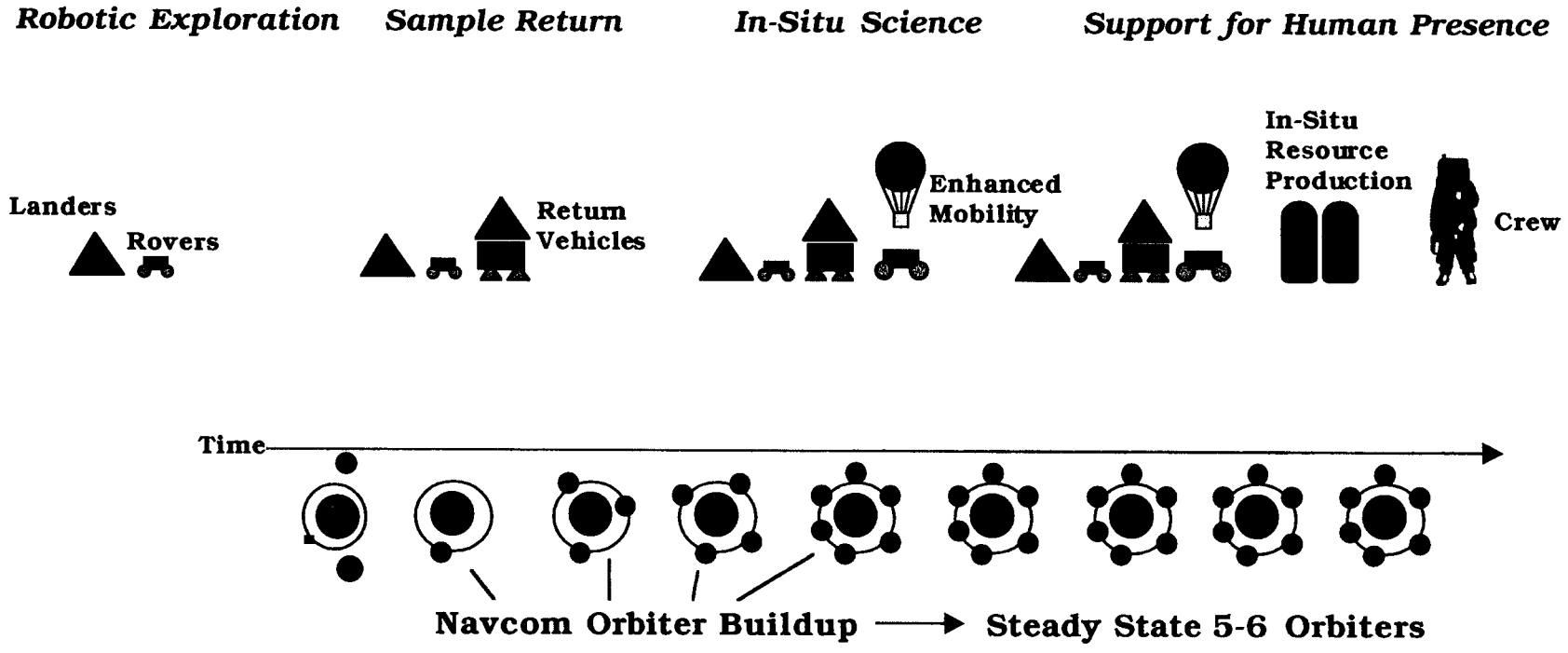
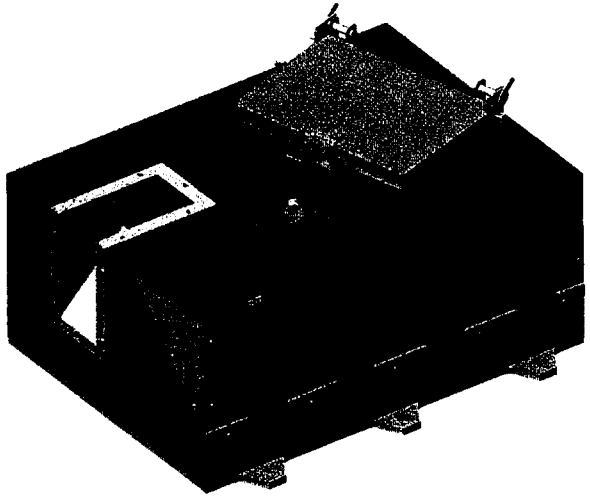
Support Human Exploration

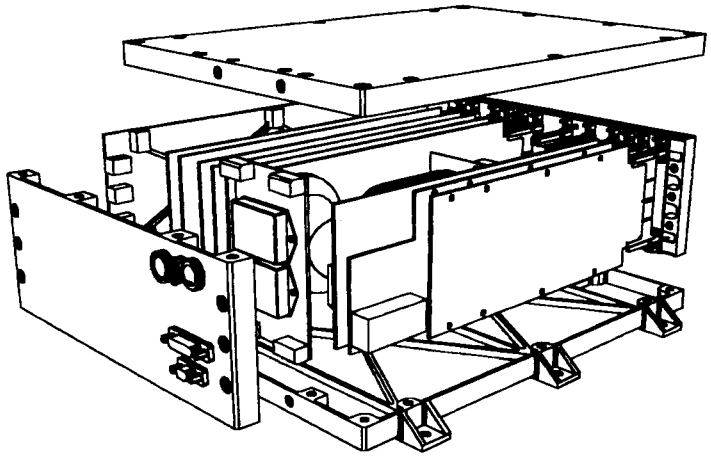


Understanding the Environment and Resources: Mars '01 Lander

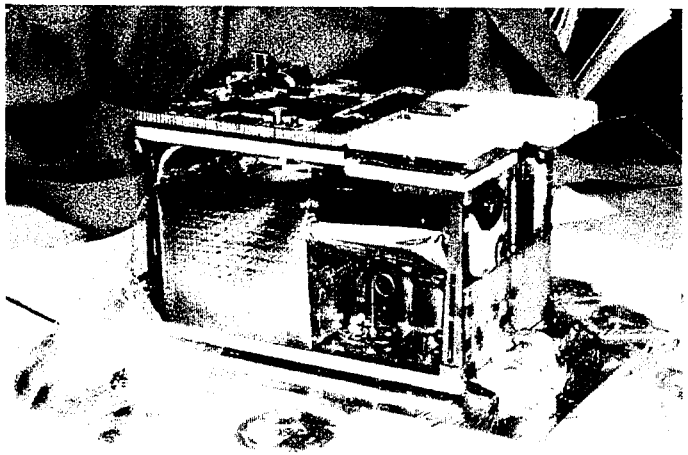
Mars Environmental Compatibility Assessment (MECA)



Martian Radiation Environment Experiment (MARIE)

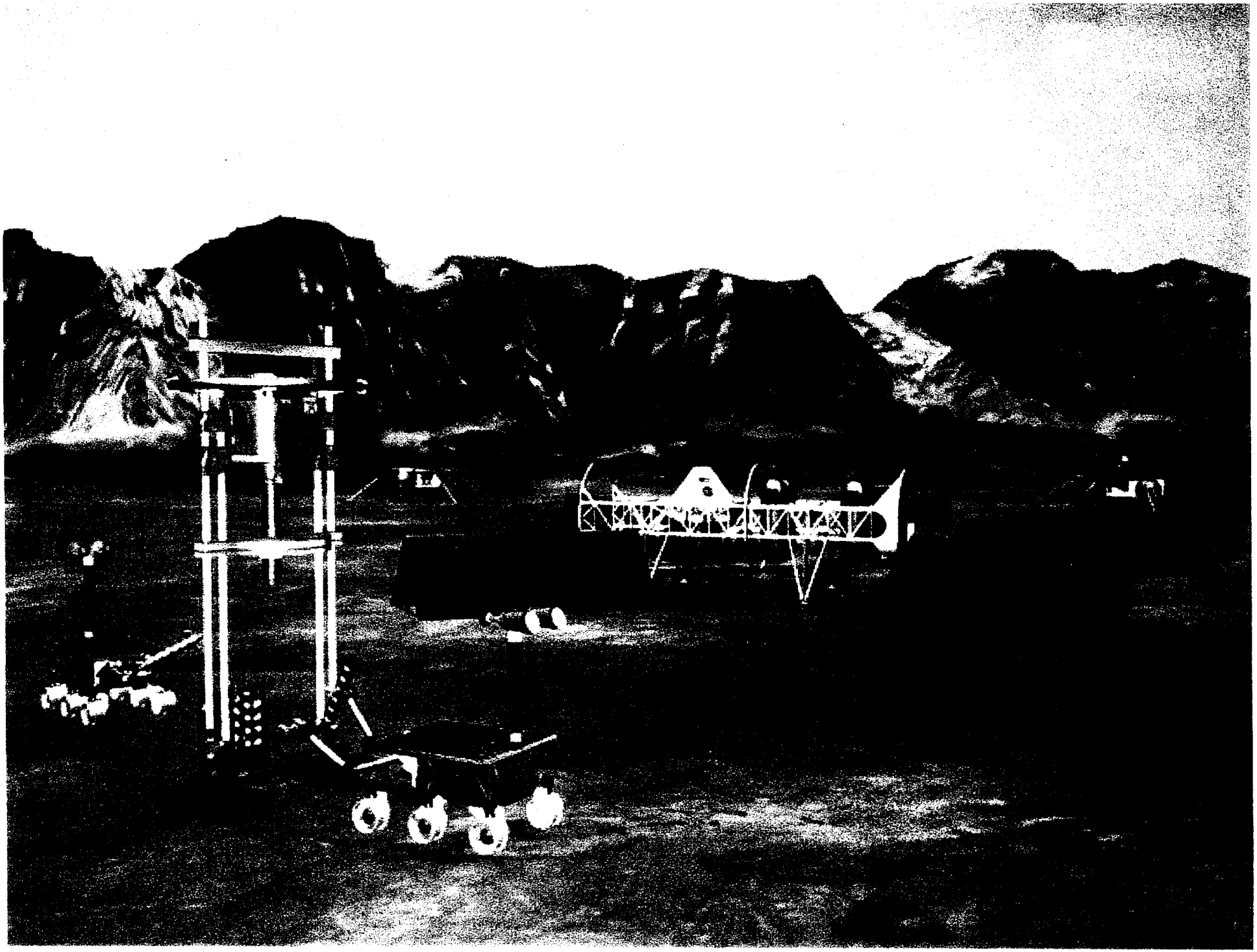


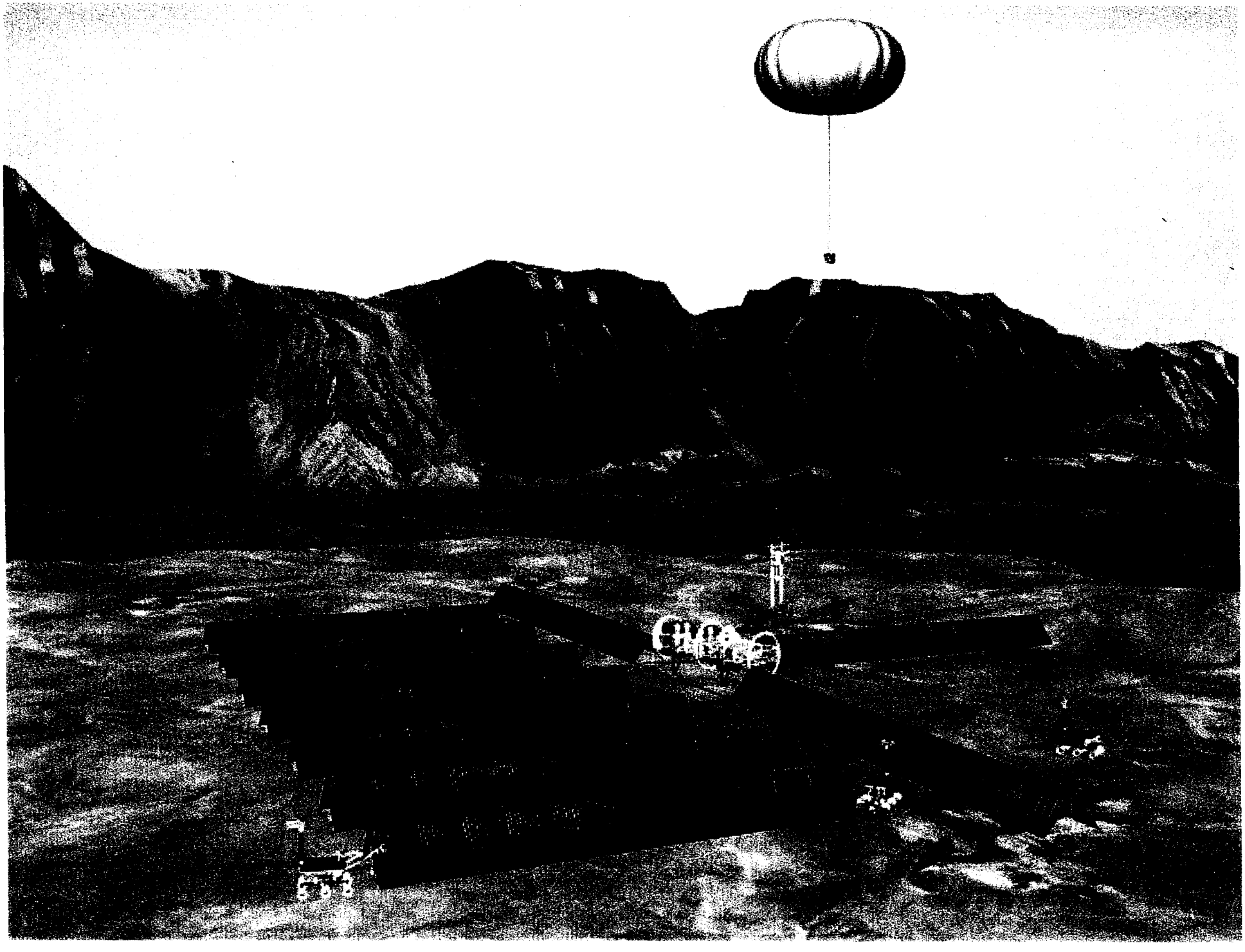
Mars ISPP Precursor (MIP)



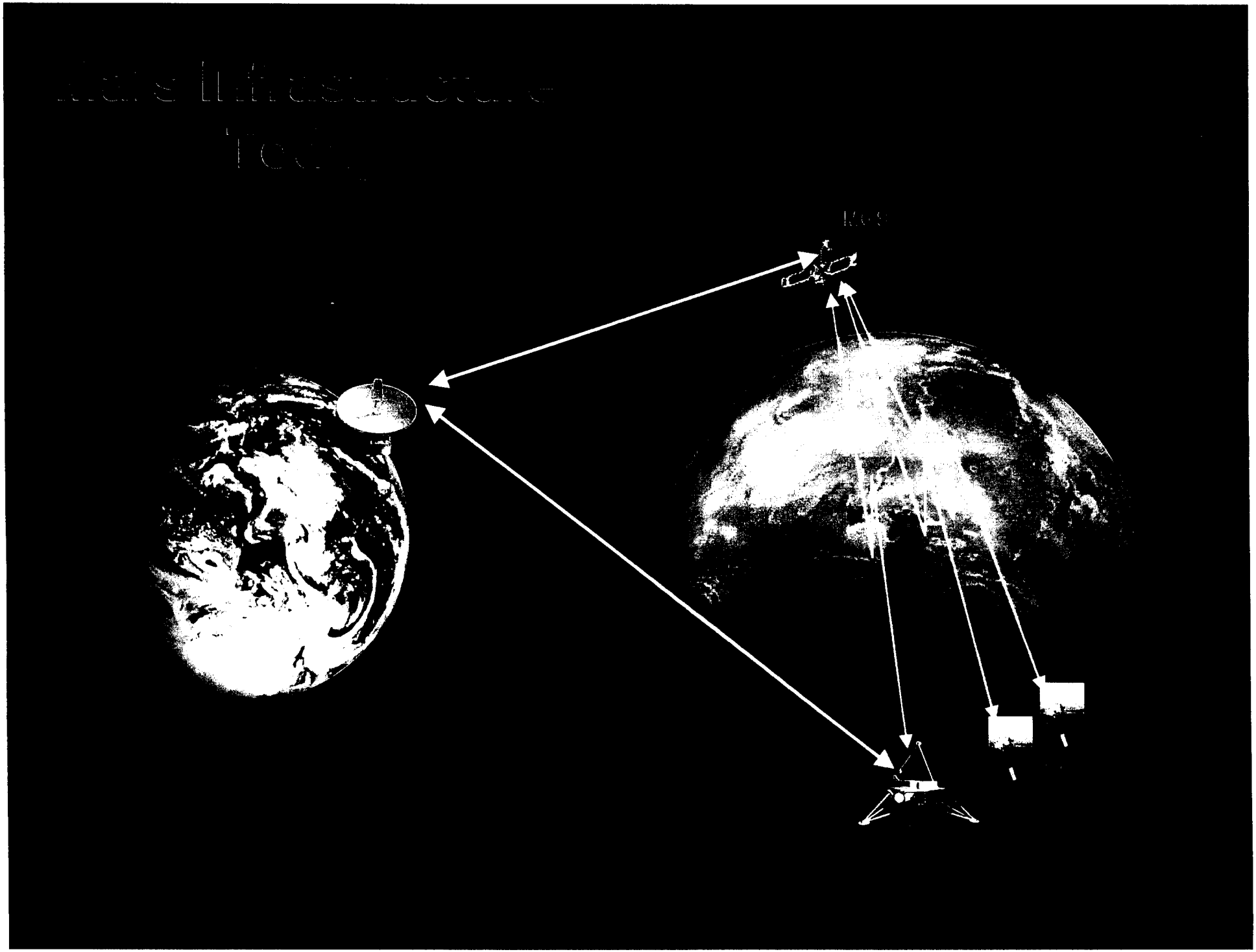
Establishing and Evolving a Permanent Presence

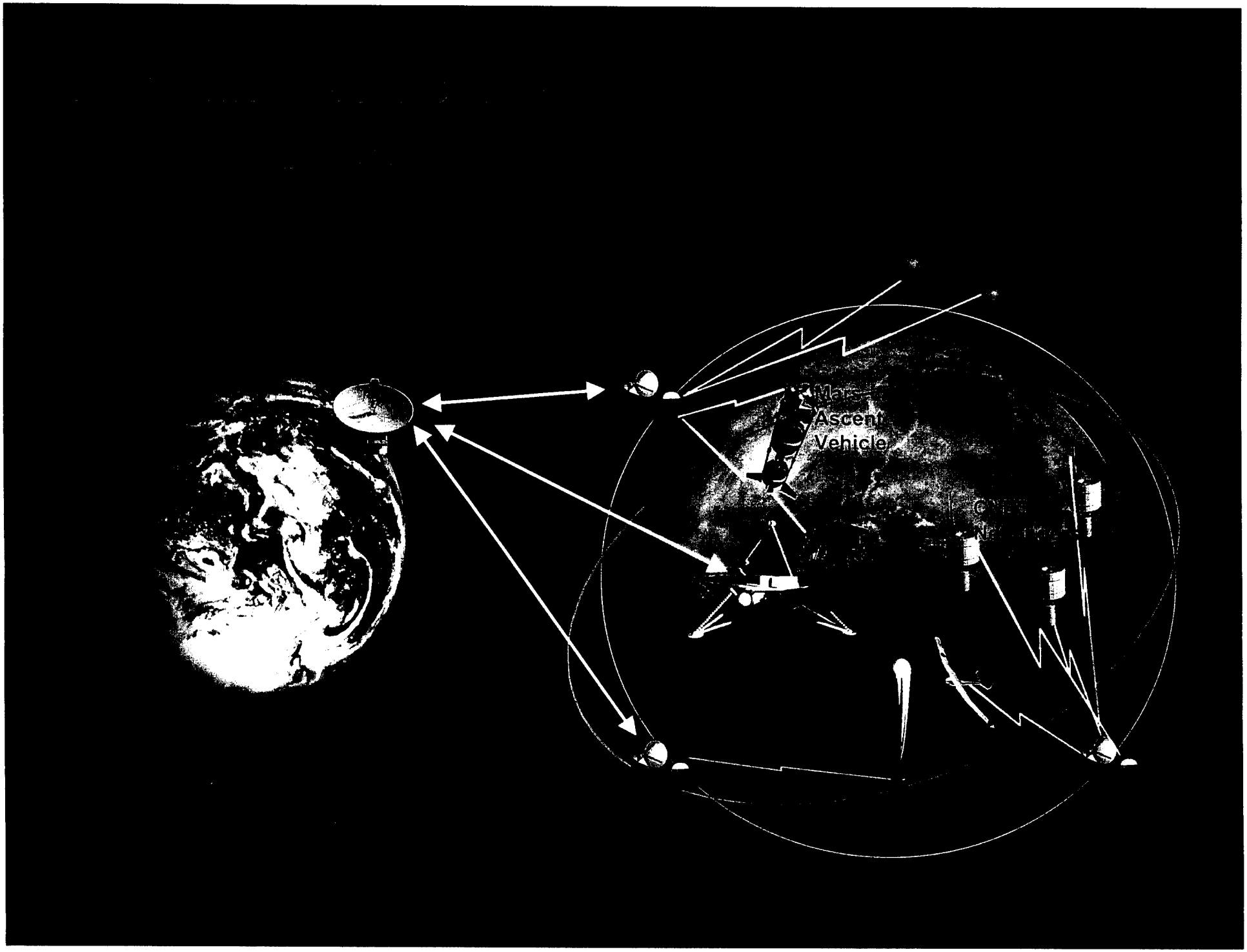
- Choose 1-2 locations
- Develop incrementally
  - On the surface: power and resources node
  - In orbit: communication and navigation nodes

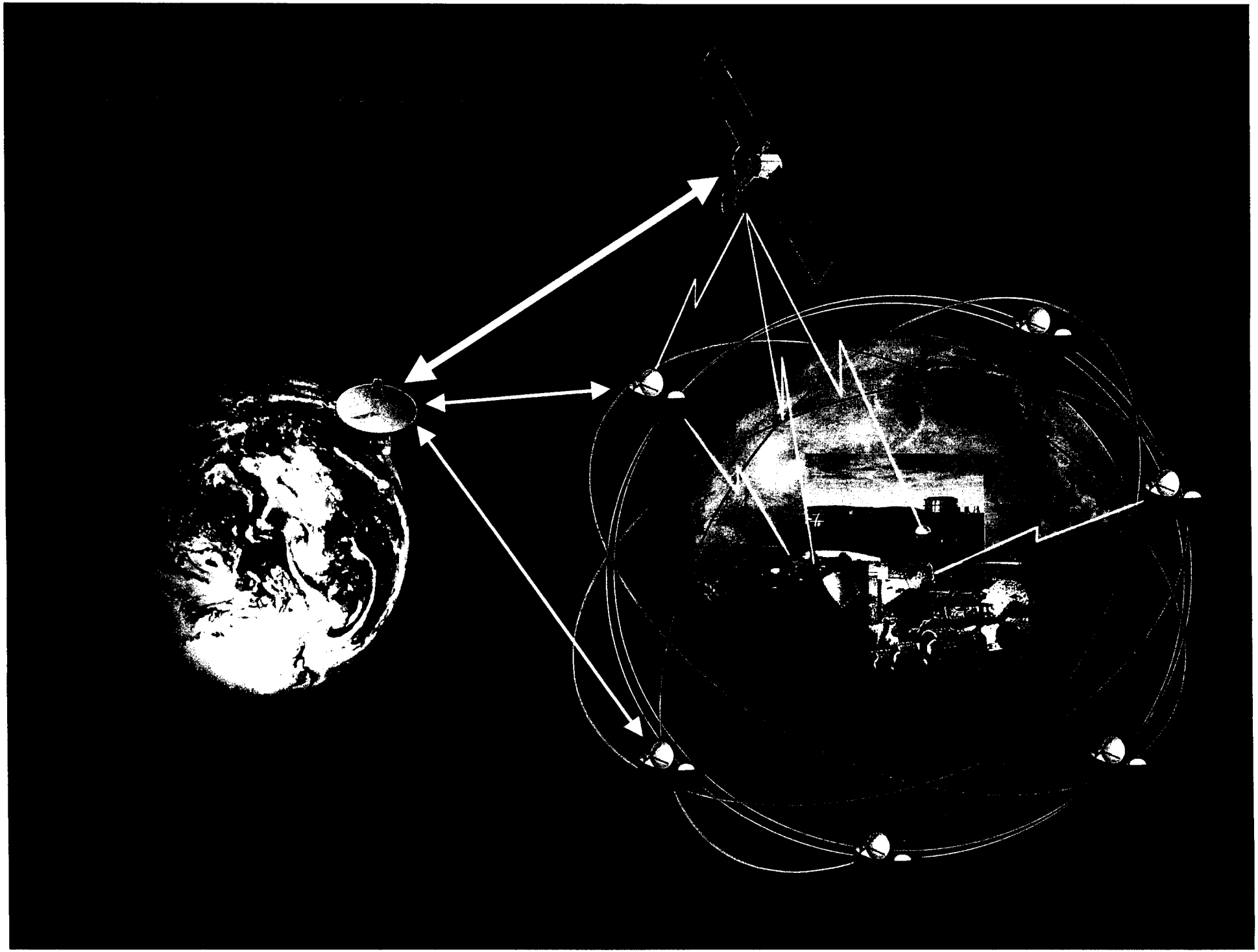




Mars Infrastructure Today

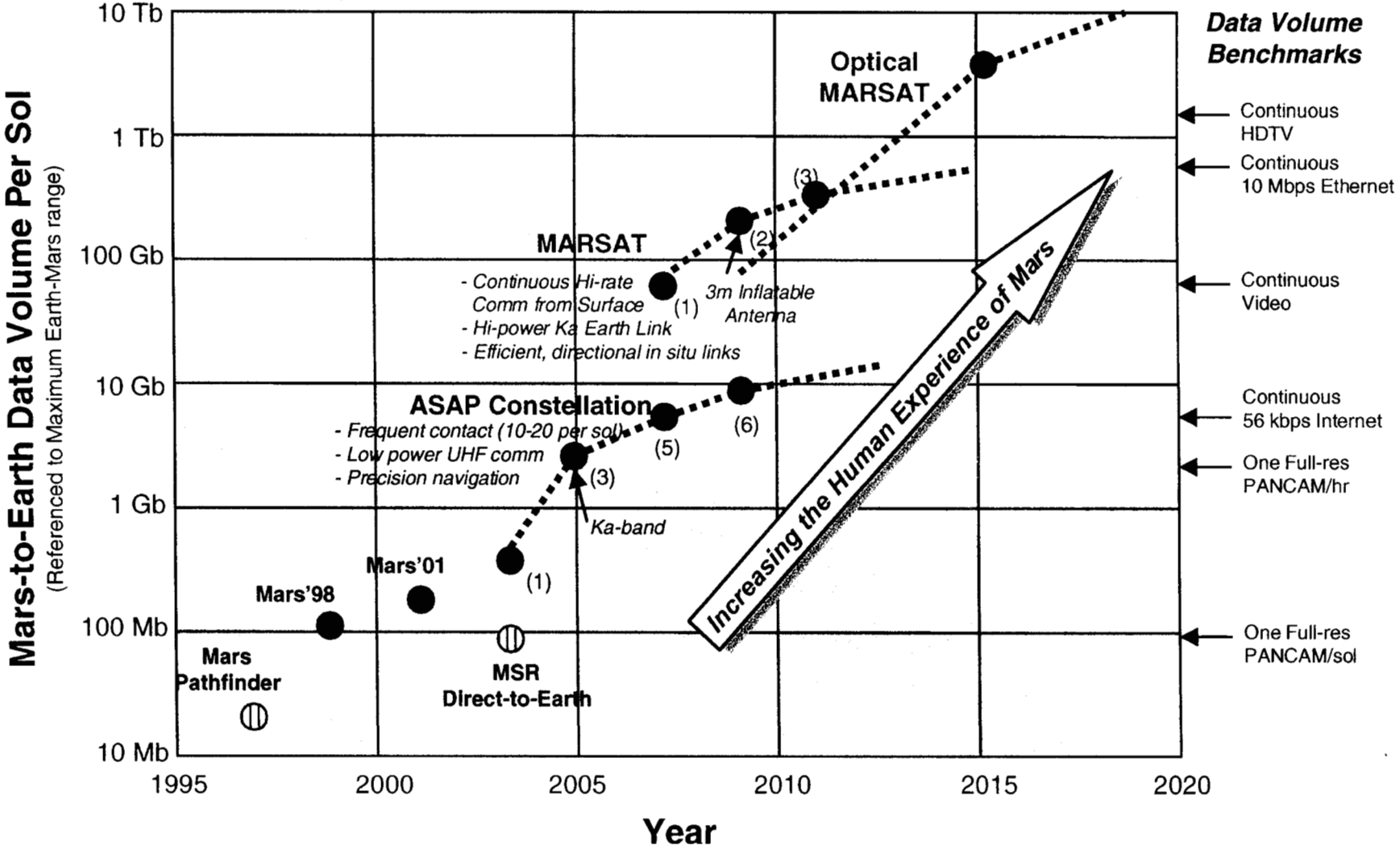


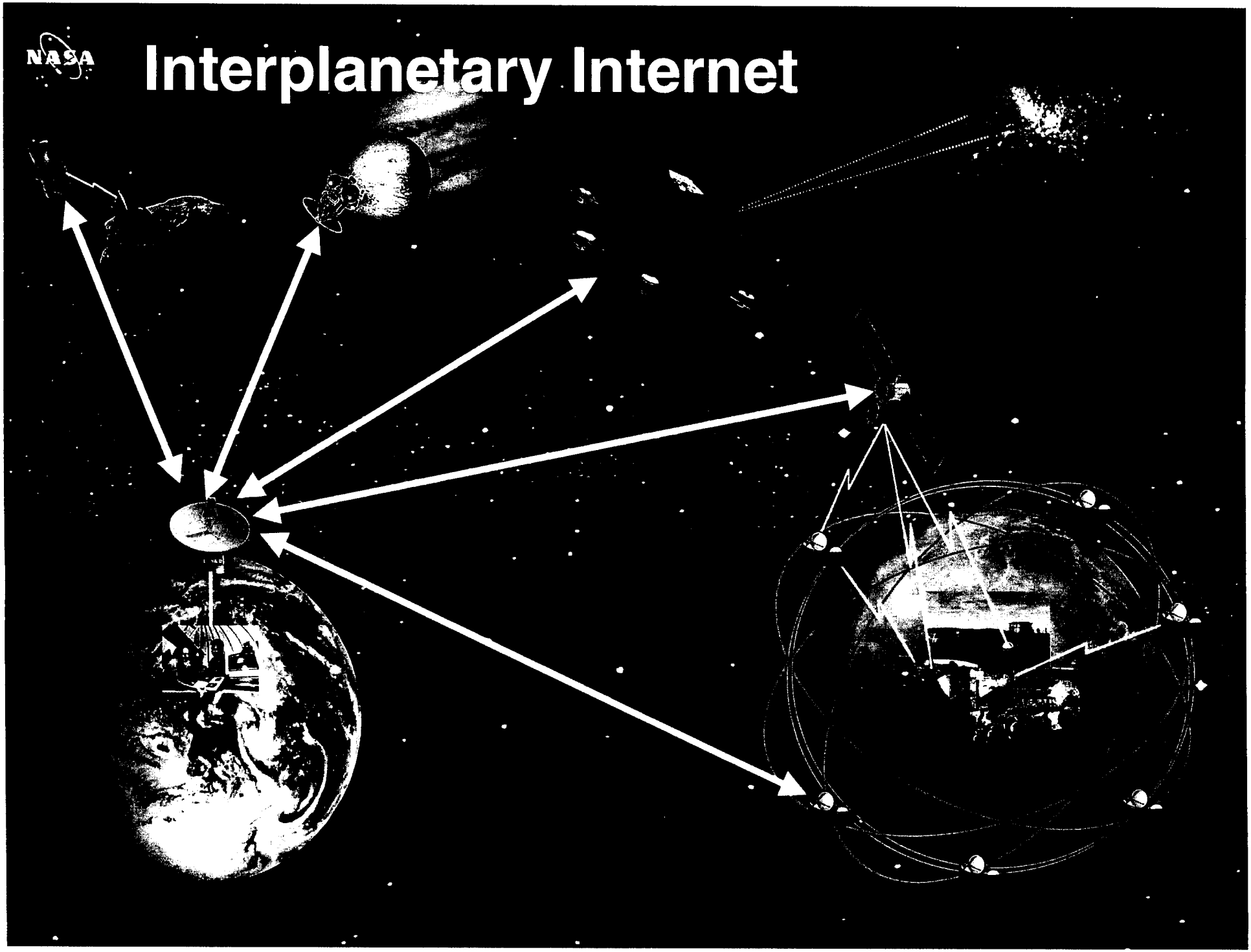

Ascent
Vehicle



Mars Network Evolution

- ***Aggressive technology infusion will allow orders-of-magnitude growth in communications capability, enabling radical increases in the fidelity of Mars virtual presence***

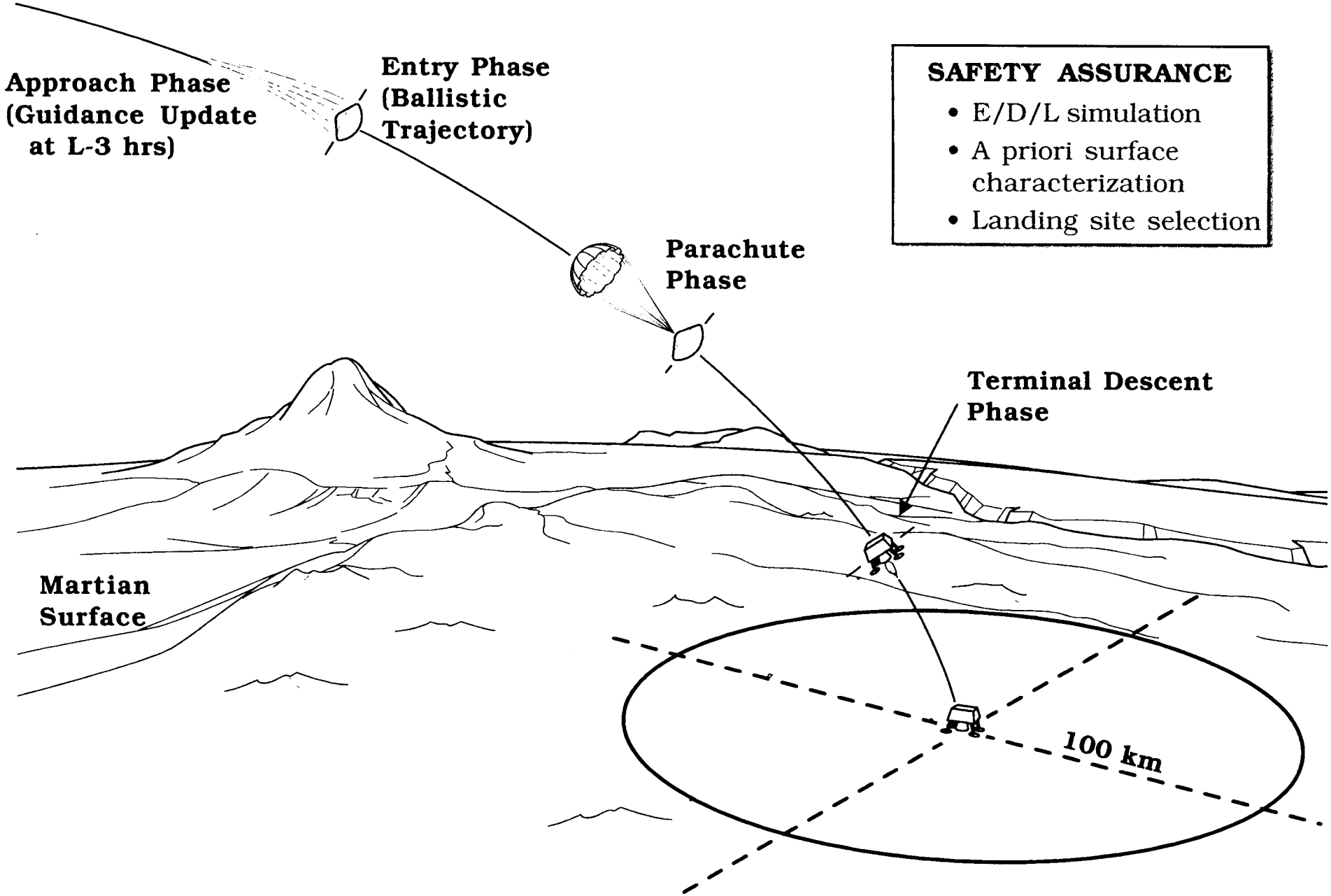



NASA
Interplanetary Internet

Key Technologies

- High-bandwidth Communication
- Precision Landing
- "Biochemistry Lab in a Teacup"
- Mobility
- *In Situ* Resource Utilization

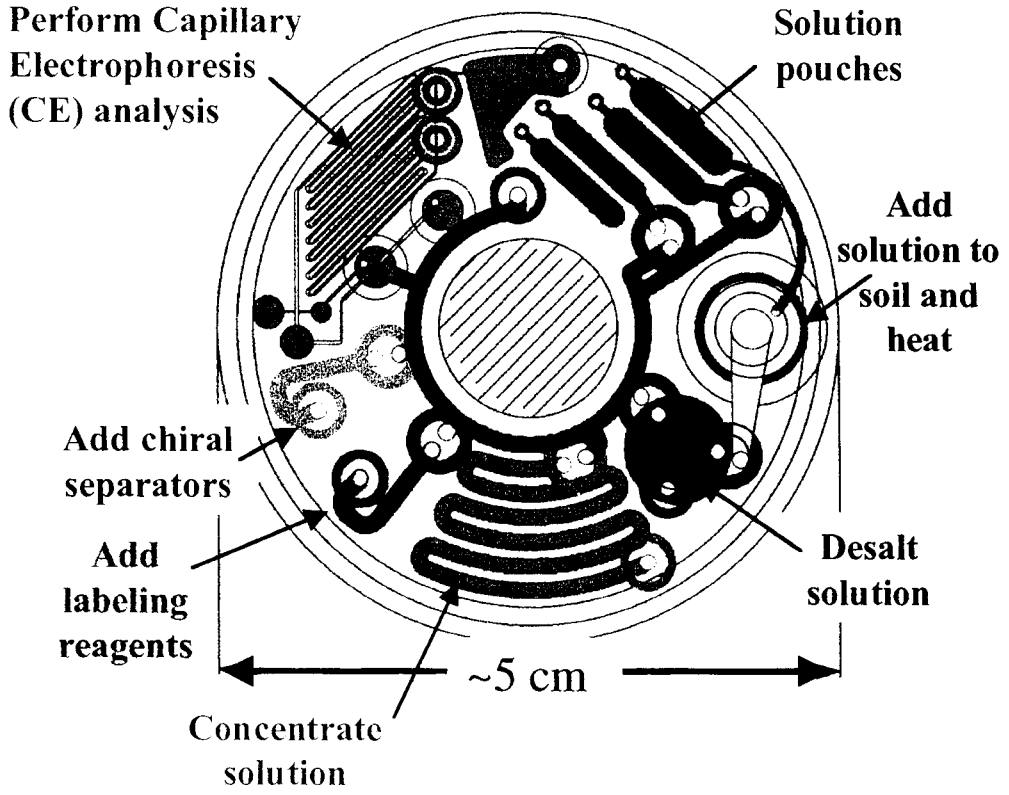
Precision Landing: Mars '98



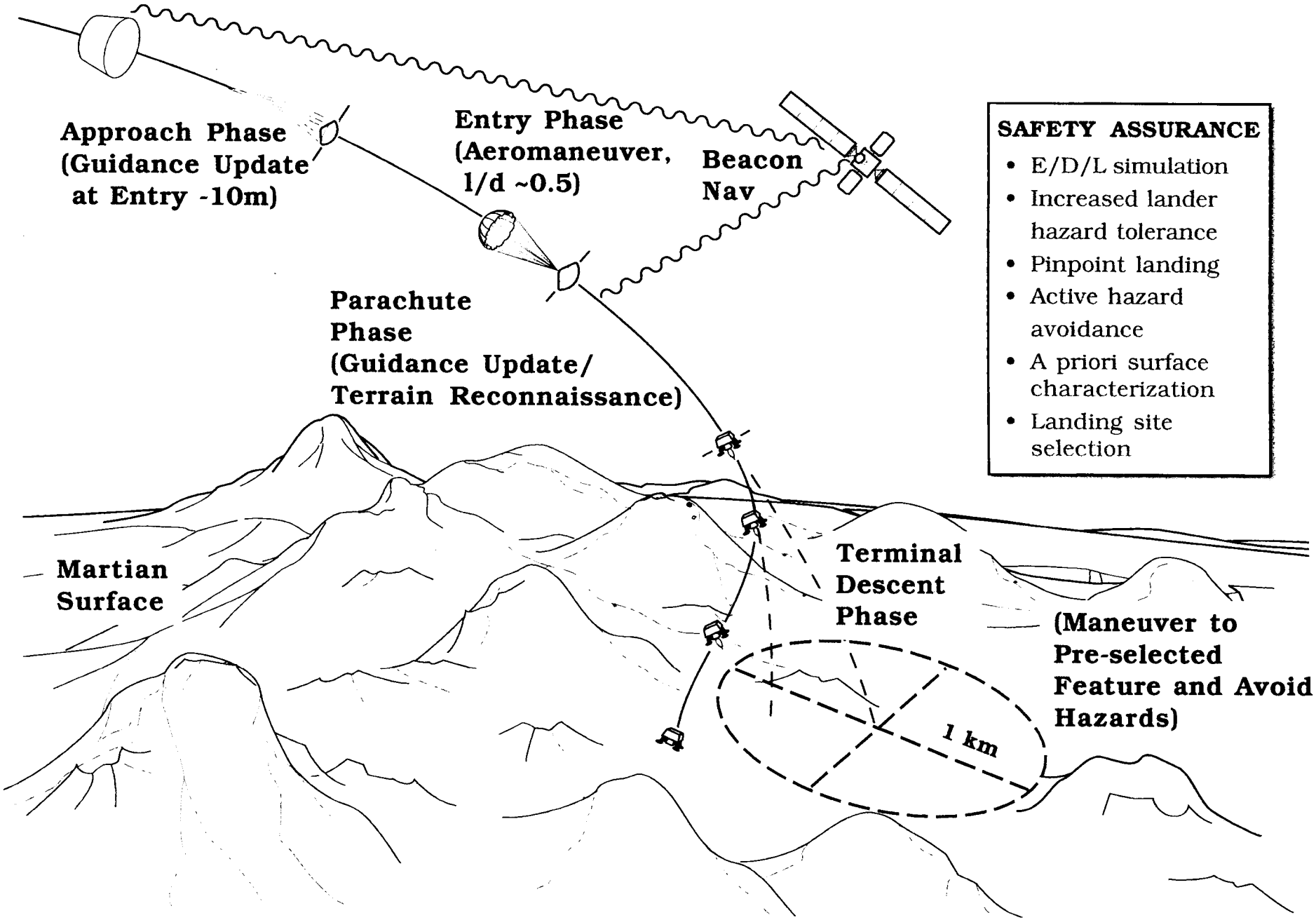
SAFETY ASSURANCE

- E/D/L simulation
- A priori surface characterization
- Landing site selection

"Biochemistry Lab in a Teacup"



Precision Landing: Mars '07/'09 and Beyond



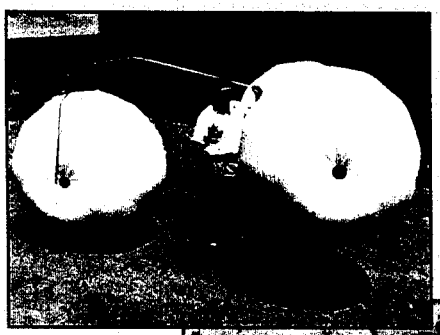
SAFETY ASSURANCE

- E/D/L simulation
- Increased lander hazard tolerance
- Pinpoint landing
- Active hazard avoidance
- A priori surface characterization
- Landing site selection

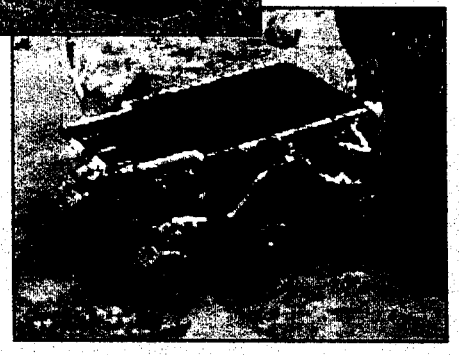
Surface Mobility Roadmap

Unlocking the secrets of the Red Planet

Innovative Mobility Systems

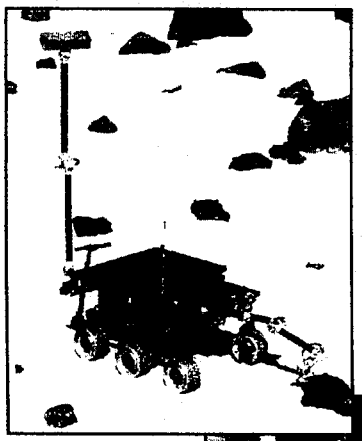


Inflatable Rover

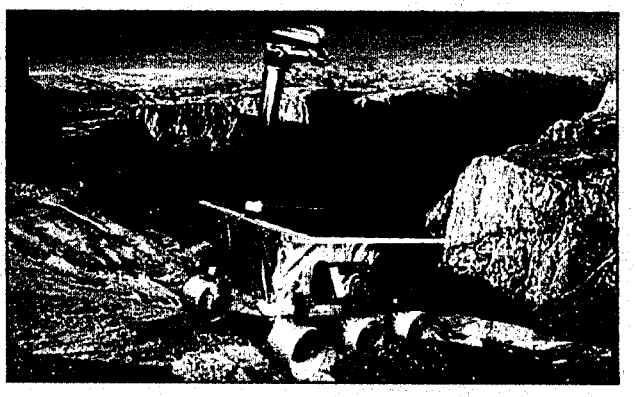


Sojourner on Mars

Mobile Sample Acquisition System

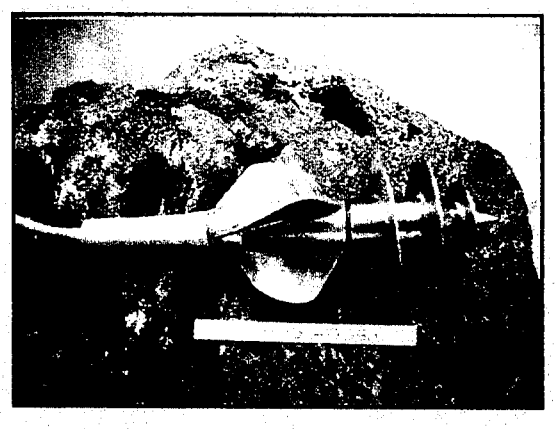


Autonomous Robotic Exploration

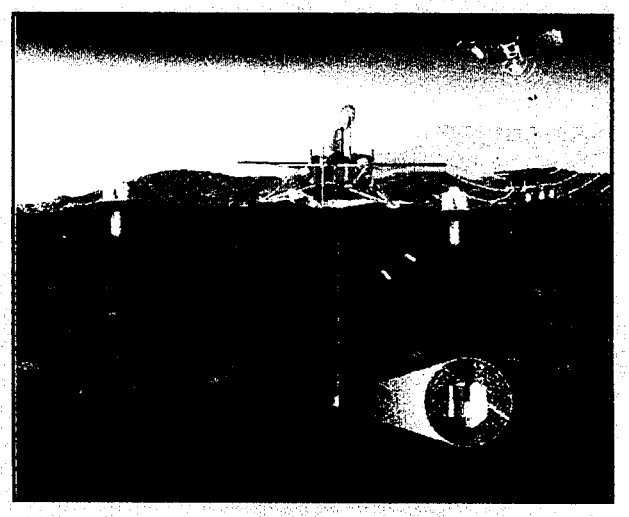


Subsurface Mobility Roadmap

Access to the subsurface of Mars with innovative robotic techniques

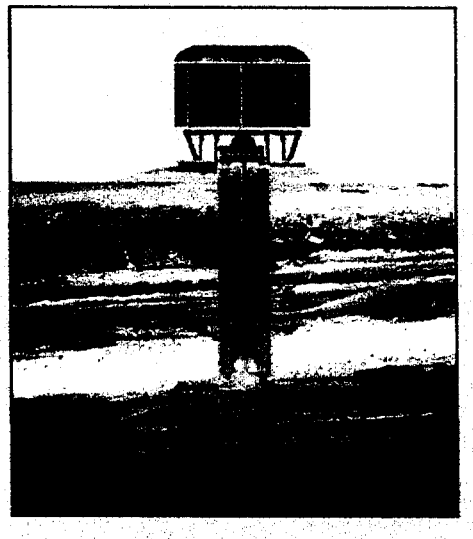


Subsurface robots for penetrating sediments and ice deposits



Deep Drilling Systems

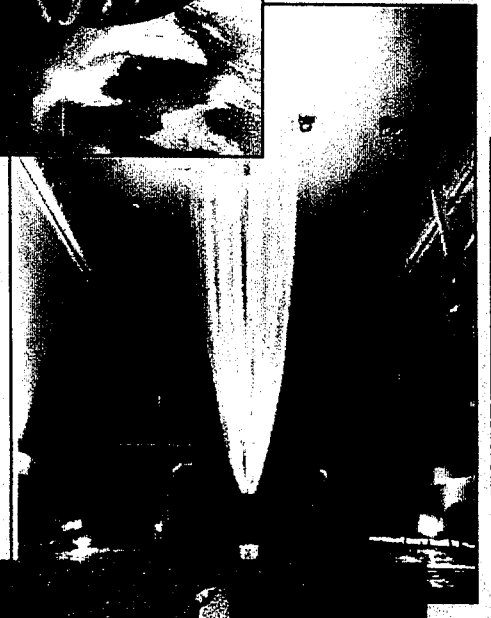
Surficial and shallow sampling of rocks and soils

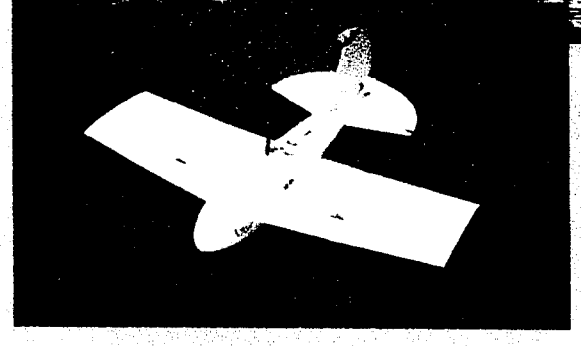


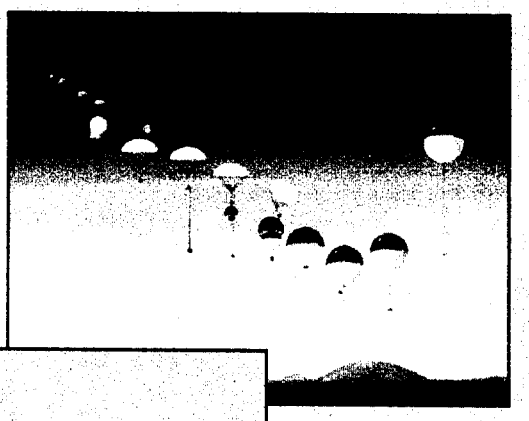
Aerial Platforms Roadmap

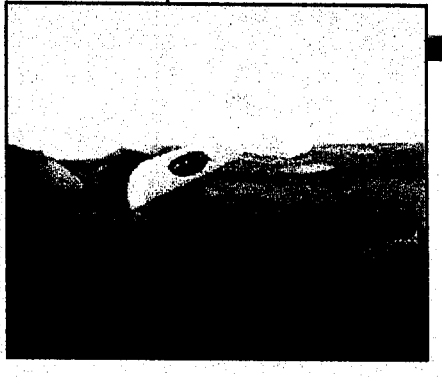
Bridging the gap between orbital and surface platform data

Earth-based technology validation

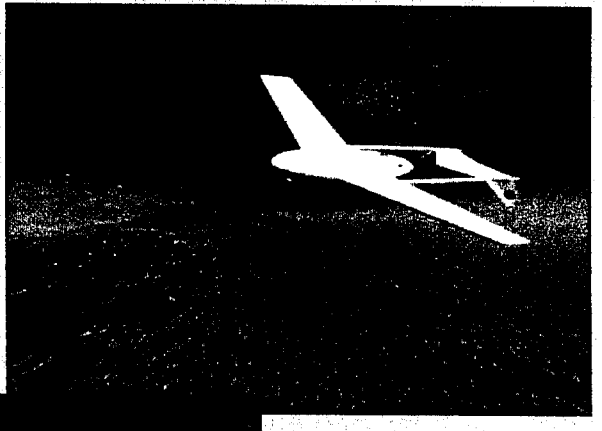


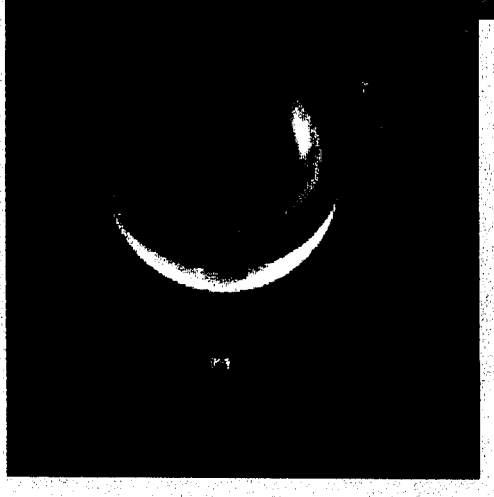






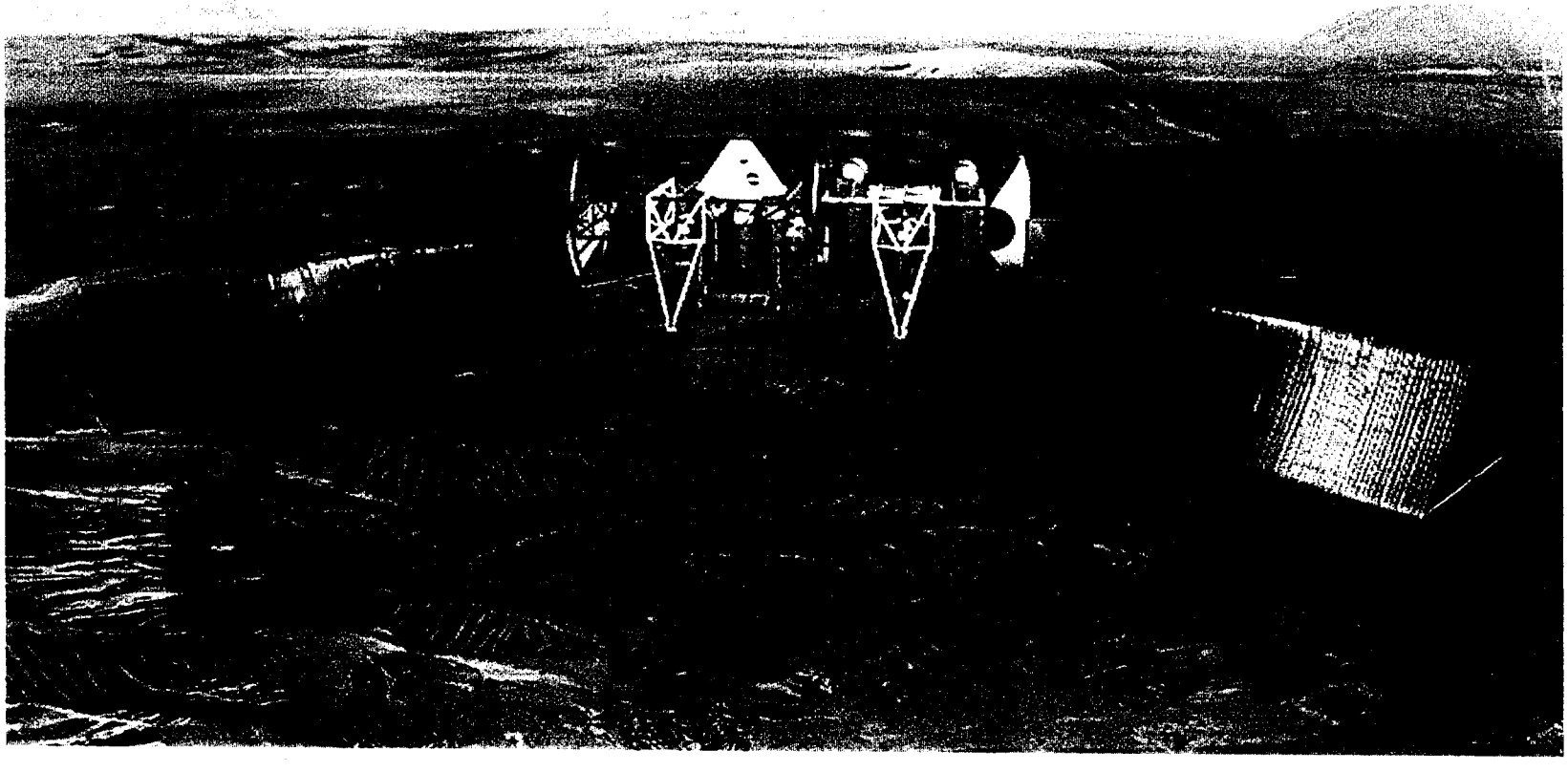
Technology demonstrations at Mars





Scientific investigations at Mars

In-Situ Resource Production Unit



Paving the Way for Future Exploration